Conceptual Model for Routine Measurements Processing and Analyses in Adaptive Intelligent Information Systems

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Abstract. A significant problem of modern society is preservation and increase of resources of human brains. A person must analyze huge amounts of data, in condition of existence of multiple obvious and hidden relations in incoming data and external influence factors in order to make correct decision. Nowadays, by the most part, data to be analyzed are results of measurements of technical and natural objects parameters. Modern artificial intelligence based information systems are not able to process efficiently enough such type of data. It requires develop a new class of adaptive and intelligent information systems that possess fundamentally new capabilities and provide new features. In the article general requirements to such systems are formulated, a conceptual model of their operation is suggested.

Keywords: measurements processing and analyses, conceptual modeling, adaptive intelligent information systems

1 Introduction

Nowadays significant attention of government is paid to the problem of preservation and increase of resources of human brains in conditions of the increasing environmental and information pressures and high responsibility for made decisions [1]. Separate research oriented projects are already in progress in both European countries and in Russia. Main well known difficulties of data and information analyses are huge amounts of data, which exceed possibilities of human brains for its perception and existence of multiple obvious and hidden relations in incoming data and external factors that have influence on solutions of the applied problems.

A relatively new challenge of data processing is lack of knowledge about problems to be solved. Often experts in subject domains are not able to identify all points that have to be checked and analyzed in the data and information streams.

An essential part of analyzed data are measurements of technical and natural objects parameters. As shown in the report of IDC [2] volume of digital universe will grow by 2020 from 4.4 trillion gigabytes to 44 trillion. Only 22% of information is now considered as a candidate for analysis. These estimations proof that it is urgent to create and deploy new generation of information systems (IS) that are capable to deal with unlimited and poorly managed streams of incoming measurements. The perspective approach for solving this problem is upcoming transition to adaptive and intelligent solutions. It requires development of new class of IS that possess fundamentally new capabilities and provide new features. In the section 2 general requirements and capabilities of such IS are discussed, the main ideas are formulated. In sections 3, 4 and 5 the proposed conceptual model for measurements processing is presented. In the section 6 the projections of the models are defined.

2 Adaptive Intelligent Information Systems requirements and expected capabilities

A new class of adaptive intelligent IS (AIIS) is expected to provide support for end users that have to deal with measurement processing and analyses tasks in the contexts of solving applied problems.

AIIS Tasks. To justify expectations an AIIS has to solve following tasks: i) reduce amount of data due to its transformation to information or knowledge; ii) build linked data and information space (ISp) and permanently support its actual state; iii) enrich data, information and knowledge using all available sources; iv) provide machine based applied problems solutions regarding measurements processing [3].

AIIS Properties. An AIIS must possess following properties: i) accumulating – to be able to support continuous systematic actualization of data, information and knowledge about the target and related subject domains; extend ISp by gathering all objective and subjective data, information and knowledge which can be correlated to the problems to be solved; ii) resource saving - to be directed to saving human brain resources, spend to understanding, analysis and estimation huge amounts of data, information and knowledge gathered by IS; iii) accessible – technologies must have low cost of ownership; iv) have theoretical background i. e. use classic mathematical theories, machine learning methods, methods of intelligent analysis and pattern recognition.

AIIS Distinguishing Features. AIIS uses a new approach to data processing and analysis, based on a new way of application of intelligent technologies.

AIIS is to be: i) intelligent – knowledge is used in all steps and phases of problems solving; ii) automatic - IT specialists are not necessary for solving data processing and analysis problems; iii) dynamic – data processing and analysis is realized in run time or real time mode, processing procedures can be adapted in accordance with changing context; iv) able to process historical data – to be able to mine useful information and knowledge from historical data taking into account historical context.

The IS with the described properties define a new class of IS, which can fit processes of measurements analyses according to the observed contexts. Intelligence of the systems allows solve applied end users tasks meaningfully using knowledge.

The modern tendencies of IS design, development and support are based on the ideas of wide usage of models –architectural, information, technological and others. The ideas have taken the form of a model driven (MDE) approach [4]. The models are in fact partial derivatives (projections / views) of the general conceptual model. All models are linked. The conceptual model reflects the general ideas of the MDE approach that is considered from the point of view of measurements processing domain. All other models are results of detailing the conceptual model's varied aspects.

3 Conceptual model principals and foundation

Development of the conceptual model has 3 goals: i) the conceptual model determines the scope of AIIS and can be conceded as a description of the AIIS class; ii) the conceptual model is to be used as a meta model for generating model of concrete AIIS, which can be used as a part of their architectural description; iii) the conceptual model is to be used as a knowledge base for storing AIIS community knowledge about models.

The proposed conceptual modal is based on a number of general ideas:

1. Real world objects are too complex for modeling, but their numerous views have simple models.
2. Real world processes are poorly predictable, too complex to be formalized, but well decomposable.
3. Feasible way to investigate the real world lies through dealing with measurements – gathering, storing, processing, analyzing.
4. Capability of consuming measurements is reachable if based on measurements progressive transformations.

Model principals. The following principles are to be used for model design.

1. The main value is knowledge; it is vital to operate with knowledge in each case.
2. Any data can be meaningful; thus, all data is supposed to be carefully processed.
3. Data that is out of date is harmful; actual state of data must be supported.
4. The resources of human minds have limits; data processing and analyzes must be organized in order to provide understanding of measurements streams.
5. Both models and processes must have internal connections and external links.
6. Models and processes must be understandable by humans and machines; they must have descriptions in terms of applied subject domains and must support standards.
7. Models and processes must be easily configured; configuration must be supported by different external tools, including GUI tools.
8. Models and processes must be hierarchical and consist of multiple simple elements.
9. Models and processes must be totally oriented on support of data and information transformations.
10. Models and processes must be adaptable at the level of structure and the level of contents.
11. Models and methods used for measurements processing must be highly flexible; they have to fit exactly spontaneously changing contexts without any delay.
12. Models and processes must correspond to the desires of consumers and available resources.
13. Models and processes must be open to integrate any external data, information, knowledge and processes.

Model foundation. Foundation for the model implementation form three technological stacks: transformation technologies, semantic web stack and IT technologies for IS design and support.

1. Transformations technologies. Transformation technologies relate to the domain of data, in particular, measurements processing and analyses. They allow consider processes of dealing with measurements as a sequence of transformations. Transformations are defined for JDL models adapted for measurements processing (MJDL) [5]. MJDL are hierarchical functional modals that define "what is supposed to be done with measurements". Measurements processing and analyses is considered at the level of initial measurements, objects and situations. The input and the output of the levels are defined in accordance with information models for initial measurements and results of their processing presentation. The transformations for MJDL are defined in the process JDL (PJDL) model. The transformations can refer to one level of MJDL, neighboring levels or to set of models. All transformations are focused on using knowledge [6].

Semantic web technologies. Semantic technologies must be considered as a world level agreement that is supported by multiple standards [7]. Their overall goal is to build giant global graph [8] interpretable and understandable by both humans and machines. Machines are responsible for solving end users problems. Experts define business politics for solving problems and provide required knowledge. Application of transformation technologies allow provide well-founded support for solving common and new tasks of measurements processing using semantic technologies. One of the perspective means for dealing with measurements is described in [9].

IT technologies for system design and support. AIIS are designed, implemented and supported using agile technologies provided by IT [10].

For AIIS an adaptive approach for systems architecture design within the agile concept has been developed [11]. The approach is based on the following principles:

1. Reuse of knowledge is preferable in comparison with code reuse.
2. Use of ready technologies ("technologies from the shelf") and ready platforms.
3. The benefits in the cost of development of a set of the systems that belong to one class are more important, than the benefits realized from development of one system.
4. Ontologies are used for describing classes of architectural solutions, separate solutions and also as means of standardization and increasing flexibility of the proposed solutions.

4 Conceptual model structure

The conceptual model (Fig. 1) gives the general view on how measurements can be consumed by humans and machines. The list of the principle entities of the model, their types and references to the groups are given in the table 1, in the table 2 types of relations between entities are briefly described. Three groups are defined according to the entities material features: i) real entities (RE) - group of real world entities (objects of the real world, AIIS, tools and means); ii) model entities (ME) - group of

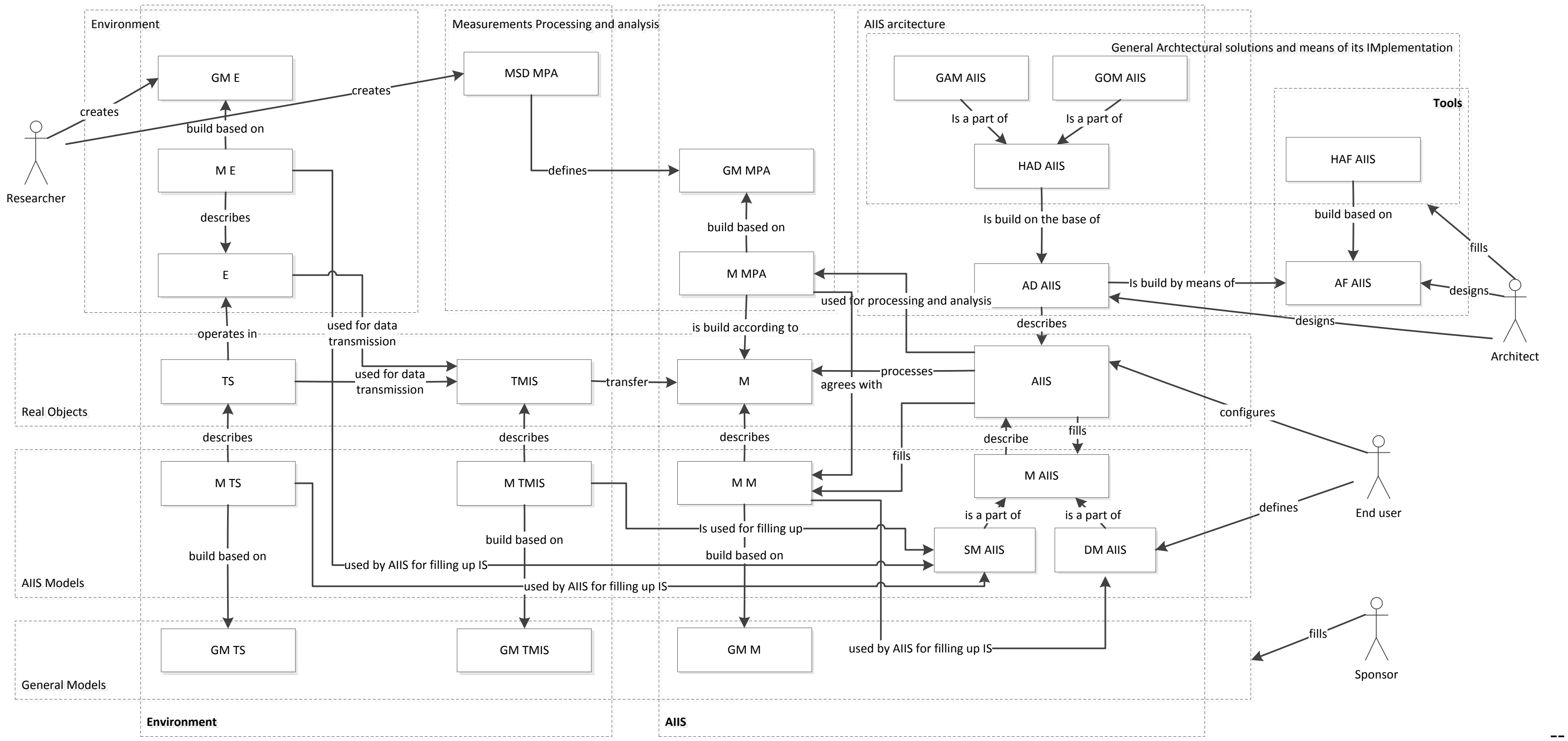

Fig 1. The structure of the proposed model for measurements processing and analyses

models (general models, AIIS models); iii) logical entities (LE) - logical domains (environment, domain of measurements processing and analyses).

Table 1. List of the principle entities of the conceptual model

Entity id	Entity name	Entity type	Relation to group
TS	target system	TSE	RE
M TS	model of the target system		ME
GM TS	general model of the target system		
TMIS	TMI system	TMIE	RE
M TMIS	model of the TMI system		ME
GM TMIS	general model of the TMI system		
M	measurements	IPME	RE
M M	model of measurements		ME
GM M	general model of the measurements		
AIIS	adaptive intelligent information system	SAE	RE
M AIIS	model of AIIS		ME
SM AIIS	static model of AIIS		
DM AIIS	dynamic model of AIIS		
AD AIIS	architectural description of AIIS		
HAD AIIS	hierarchy of the architectural descriptions of AIIS		
GAM AIIS	general architectural models of AIIS		
GOM AIIS	general ontological models of AIIS		
AF AIIS	architectural framework of AIIS	AFE	RE
HAF AIIS	hierarchy of architectural frameworks of AIIS		ME
E	environment	TSEE	LE
M E	model of the environment		ME
GM E	general model of the environment		
M MPA	model for measurements processing and analyses of TS parameters	MPAE	ME
GM MPA	general model for measurements processing and analyses of TS		
MSD MPA	model of the subject domain of measurements processing and analyses		LE

The types of the entities are set according to the real world objects that they relate to: i) target system entities (TSE) - entities related to the target system and its description; ii) TMI system entities (TMIE) - entities related to the TMI system and its description; iii) initial & processed measurements entities (IPME) entities related to initial and / or processed measurements and their descriptions; iv) system architecture entities (SAE) - entities related to the AIIS and its architecture; v) architectural framework entities (AFE) - entities related to architectural frameworks; vi) target system environment entities (TSEE) - entities related to target system environment; vii) measurements processing and analyses entities (MPAE) - entities related to measurements processing and analyses.

Table 2. Types of the relations of the conceptual model

Relation name	Object	Subject	Description
build based on	ME	ME	models are built on the base of general models
describe	RE	ME	models describe objects of the real world
operates in	TS	E	target system functions in the environment
used for data transmission	RE	TMI Systems	real entities transfer data using TMI system
used by AIIS for filling up IS	ME	ME	model entities of real objects are used for filling up AIIS models of information space
transfer	TMI S	M	TMI systems transfer measurements
define	MSD MPA	GM MPA	model of the subject domain of measurements processing and analyses defines general model for measurements processing and analyses of TS
is build according to	M M	M MPA	model of measurements is build according to model for measurements processing and analyses of TS
agree with	M M	M MPA	model of measurements must agree with model for measurements processing and analyses of TS
fills	AIIS	M E	AIIS fills model of measurements; AIIS fills model of AIIS
processes	AIIS	M	AIIS processes measurements
used for processing and analyzes	M MPA	AIIS	model for measurements processing and analyses of TS is used in AIIS for dealing with measurements
to be part of	ME	M AIIS	dynamic model of AIIS and static model of AIIS part of AIIS model
is built by mean of	AD AIIS	AF AIIS	architectural description of AIIS is build used architectural framework of AIIS

Description of the conceptual model. A Target system (TS) is a system to be observed or investigated. Environment (E) is a context for TS, it defines conditions in which TS operates. A TS is used only for technical systems. For investigation of natural systems E concept is applied. A technical system is described by a target system model (M TS), for a natural system an environment model (M E) is build. A M TS is a set of models which describe TS. Models of end systems are built on the base of generalized models (GM TS and GM E).

Results of parameters measurements of all systems are transferred to AIIS by means of telemetric IS (TMIS). A model of a TMIS (M TMIS) is a set of models which describe the TMIS. M TMIS is based on a generalized model of telemetric systems (GM TMIS). Results of TS parameters measurements (M) are described in accordance with measurement models (M M), which are built on the base of generalized measurement model (GM M). Processing of results of measurements is executed in accordance with models for measurements processing and analyses of TS parameters (M MPA). Similar to models of TS and models of TMIS models for measurements processing and analyses are based on generalized models (GM MPA). The list of methods and algorithms to be used in AIIS is defined by a subject domain model of measurements processing and analyses (MSD MPA).

Architecture description of AIIS (AD AIIS) is made in accordance with standard [12] and hierarchy of the architectural descriptions of AIIS (HAD AIIS). HAD AIIS include generalized architecture (GAM AIIS) and ontological (OM AIIS) models.

Data, information and knowledge generated during the IS operation are stored in data, information and knowledge model (DIK model) that is the essential part of AIIS model (M AIIS). M AIIS contains both static and dynamic DIK that are located in static (SM AIIS) and dynamic (DM AIIS) models of AIIS model correspondingly. DM AIIS is used to save information about current state of the system and SM AIIS contains constant or rarely changed data. A term architecture framework (AF) defines 2 separate concepts. On one hand, AF is a tool for designing applied AIIS, on the other hand, it is "conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders" [12], or simply best practice. AF defines frameworks for building domain oriented IS. To design AF a hierarchy of architectural frameworks of AIIS (HAF AIIS) is used. An important part of AF is model MKB. MKB is a repository. All models are stored in MKB and are available to developers of one or different organization.

5 Stakeholders and scenarios of application

Main AIIS stakeholders are end users, architects, sponsors and researchers. An end user is an expert of an applied subject domain that operates technical systems or is an expert who solves problems related to natural systems. An architect is an IT specialist or group of specialists who design AIIS with the use of AF. Sponsors fill the repository of the general models with new models or modify existing models. Researchers of natural systems and environment create new models / modify existing models that describe natural objects. Researchers develop new methods and algorithms.

MKB is available for both researchers and developers. It is of primary importance for all architects and analyst. They can form their own models with the help of a toolbox. The toolbox is a GUI instrument with the help of which a user can populate MKB, choose necessary models from the list of available reference models, transform and aggregate them in order to receive necessary target model. Received models are used as an element of an architectural description of the target system. So, a user receives a validated model and minimizes risks of dealing with a wrong model and can save time for model development.

The generalized scenario of the AIIS operation is shown in Fig. 2. An AIIS gathers results of measurements and use them for building measurement model. Activities initiated by the users are event based. A user forms requests for measurements processing and analyses. According to the request, model of AIIS is build. The model defines the structure and the content of DIK which are required to be received about the target natural or technical object as a result of the carried experiment. Then the model of measurements that reflect the expected raw data and results of its processing and analyses is created. For building a measurement model the models of target system and TMI system are required.

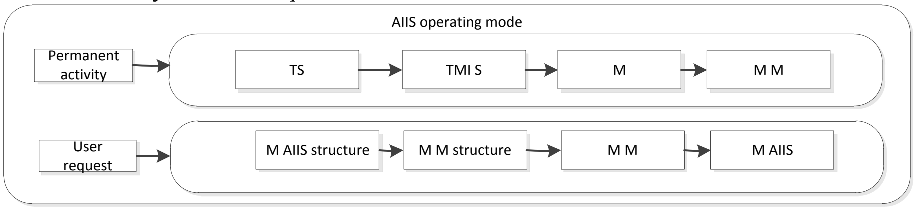

Fig 2. Generalized scenario of the AIIS operation

Measurements processing is a linked sequence of transformations of raw data. As the transformations go, the measurement models and AIIS models are filled. Often for making transformations external information and knowledge about the target system is to be used.

Table 3. Conceptual model projections

Projection	Id	Description
All Viewpoint	AV	integrates all view points; defines architectural context
Systems Viewpoint	SV	considers a system as an aggregation of interacting subsystems; is used as a structural description of the system
Functional (Capability) Viewpoint	CV	defines potential capabilities of a system for solving applied problems
Model Viewpoint	ModV	describes a system in terms of used models
Object Viewpoint	ObjV	describes a system in terms of an object model
Data, Information and Knowledge Viewpoint	DIKV	considers basic structures for data, information and knowledge representation and a set of specialized representations dependent on the solved problems
Behavior (Process) Viewpoint	BV (PR)	considers a system as a set of working scenarios, executable activities, supported business processes
Services Viewpoint	SvcV	considers a system as a set of services, describes functionality of a system at different levels of abstraction
Architectural Viewpoint	AV	considers architecture of a system; processes of system architecture design, systems development and support
Platform ViewPoint	PV	considers a system as a set of platforms used for its implementation
Standards Viewpoint	StdV	considers actual technical standards, methodologies, instructions, restrictions with which the system complies

6 Conceptual model projections

The list of projections contains views of the concept model that provide its overall detailing. They are coordinated with the standard [12]. The descriptions of the projections are given in table 3.

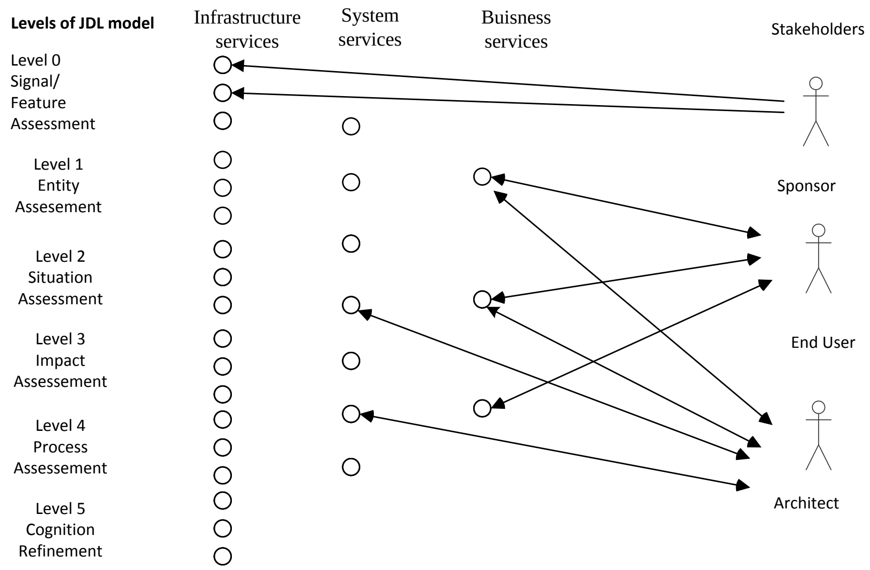

Fig. 3. Service process JDL model

As an example it is suggested to consider a service-oriented projection (Fig. 3). This model is most closely related to the implementation tasks. SvcV describes AIIS as set of services and business processes (BP). For the services 4 levels of functioning are defined. Infrastructure services (f) are usually elementary services. They are fragments of program code, i.e. java code. Each infrastructure service is associated with the certain level of JDL model. System services (y) are composite services. These services implement BP that assumes calling both Infrastructure and other System services. A System service as a rule is connected with 2 neighboring level of JDL model. Business services (b) are composite services which are described in terms of subject domain. They are to be formed on the base of system and other business services. External (high-level) (x) services that are targeted to support B2B interactions be also defined. They are similar to business services but without GUI.

There are 4 different types of services: functional services (s), DIK services (d), interpreters (engines) (e) and supporting services (p). Functional services implement target procedures of processing and analyses. DIK services provide access to DIK resources. Engines are interpreters of scripting languages. Supporting services are services that support life cycle, security, etc.

The services are distributed among levels of JDL model. Each business process (BP) in AIIS is considered as service, and each service can be realized as BP. In the context of SvcV business process is a sequence of calls of services described in BPEL style. BP can be either static or dynamic. The general idea of the proposed Service Process JDL (SPJDL) model is given in Fig.3. For Service description following notation can be suggested. A service is described as $<T_{<level><jdl>}>$, where T - type of services, *level* - level of services, *jdl* - level of JDL model; $T = \{s, d, e, p\}$, $T = \{s, d, e, p\}$, $level = \{f, y, b, x\}$, $jdl \in [0; 5]$.

Different stakeholders work on different levels. An End user has an access only to Business Services. An Architect by the most part works with system and business services. Sponsors usually have rights to receive information about services in MKB and add new services into MKB. Commonly they work with Infrastructure services. Developers and analyst have full access to all levels.

7 Conclusion

In the paper an approach for solving a problem of analysis huge amounts of incoming data, in condition of existence of multiple obvious and hidden dependencies and external factors is discussed. The main idea of suggested approach to AIIS development is creation of AIIS conceptual model, which is to be used as meta model. Application of the conceptual model allows formalize procedures of creating models of applied systems of the domain level. Using transformations developers can form their own models by detailing projections of the conceptual model. The model saves time for model development by means of model reuse and allows receive reliable validated end models. They can be reused both in the frame of product lines and independent AIIS.

The discussed approach provides support for end users who have to deal with measurement processing and analyses tasks in the contexts of solving applied problems by means of reducing amount of data and increasing its utility. It is achieved due to building linked data and information space, using all available sources of information and knowledge and data enriching techniques, support machine learning procedures regarding measurements processing. Procedures for measurements processing and analyses can be adapted in accordance with operative and historical context. It simplifies the tasks of exerts of data processing and analysis domain at the stage of system design

The approach can be implemented using existing technologies in combination with semantic technologies.

For creation of the conceptual model our practical experience in realization projects in different subject domains such as monitoring state of complex technical systems, intelligent GIS systems, medicine was used. All these systems were based on jdl model, detailed analysis show that they have many common features and use similar models.

At present it is used in the project of medical data processing and analyses for Federal Almazov North-West Medical Research Centre [13]. The project is executed in International laboratory "Information Science and Semantic Technologies" [14]. The detailed description is available on the web site of the Laboratory.

Future activity is planned to be directed to population the conceptual model with new concrete models and adding new transformation features.

References

1. National Technological Initiative. NeuroNet segment. CoBrain project (2015); http://government.ru/en/news/20118/
2. IDC Research. The Digital Universe of Opportunities: Rich Data and the Increasing Value of the Internet of Things (2014); http://idcdocserv.com/1678
3. IBM. 5 Things To Know About Semantic Technologies (2013); https://www.ibm.com/developerworks/community/blogs/5things/entry/5_things_to_know_about_the_semantic_technologies?lang=ru
4. Model-Driven Architecture: Vision, Standards And Emerging Technologies. http://www.omg.org/mda/mda_files/Model-Driven_Architecture.pdf
5. Vodyaho A., Zhukova N. Implementation of JDL Model for multidimensional measurements processing in the environment of intelligent GIS. International Journal of Conceptual Structures and Smart Applications,. 2(1). P. 36-56. (2014)
6. Vodyaho A., Zhukova N. System of Ontologies for Data Processing Applications Based on Implementation of Data Mining Techniques. Supplementary Proceedings of the 3rd International Conference on Analysis of Images, Social Networks and Texts. (Yekaterinburg, 10–12, April, 2014). M.: Higher School of Economics Publishing House, P. 107–120 (2013).
7. W3C Standards; https://www.w3.org/standards/
8. Berners-Lee T. Giant Global Graph (2007); http://dig.csail.mit.edu/breadcrumbs/node/215
9. Blazegraph database by SYSTAP, LLC (2016); https://www.blazegraph.com/
10. Principles behind the Agile Manifesto. http://www.agilemanifesto.org/principles.html
11. Vodyaho A.I. ., Zhukova N. Building Smart Applications for Smart Cities – IGIS -based Architectural Framework. Proceedings of 19th International Conference on Urban Planning and Regional Development in the Information Society. (Austria, Vienna, 21–23 May, 2014). Vienna: CORP. P. 109–118 (2014)
12. International Standard ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description (2011)
13. Federal Almazov North-West Medical Research Centre; http://www.almazovcentre.ru/?lang=en
14. International laboratory "Information Science and Semantic Technologies"; http://semantics.ifmo.ru/en/87807/International_laboratory_Information_Science_and_Semantic_Technologies.htm/